CLAIMS

1. A method of controlling a vessel mooring system said system including at least one mooring robot for releasably fastening a vessel floating at the surface of a body of water to a terminal, the mooring robot including an attractive force attachment element displaceably engaged to a base structure of said mooring robot said base structure affixed to said terminal, said attractive force attachment element being releasably engagable with a vessel surface for making fast the vessel with said terminal, the mooring robot providing active translational movement of the attractive force attachment element relative to the base structure to allow thereby the movement of a vessel in a direction selected from any one or both of

(i) an athwartship direction, and

(ii) a longitudinal direction,

said method, after the associating of the vessel with the mooring system by allowing the vessel surface to be engaged by the attractive force attachment element and the establishing of an attraction between said vessel and said mooring robot, comprises;

(a) measuring the attractive force between the surface and the attractive force attachment element, for the purposes of determining the holding capacity in at least one of

(i) parallel to the attractive force direction,

(ii) normal to the attractive force direction and horizontally, and

(iii) normal to the attractive force direction and vertical,

(b) measuring the force between the attractive force attachment element and the base structure of the mooring robot at least in a direction selected from anyone or more of

(i) parallel to the attractive force direction,

(ii) normal to the attractive force direction and horizontally, and

(iii) normal to the attractive force direction and vertical,

(c) monitoring the relationship between the attractive force and the force(s) measured in (b), wherein an alarm is triggered when any one or more of the forces measured in (b), in a direction to tend toward allowing relative movement between the attractive force attachment element and the said vessel, approaches an attractive force dependent holding capacity in the direction to tend towards allowing relative movement of the attractive force attachment element with said vessel.

2. A method as claimed in claim 1 wherein the attractive force attachment element is a variable attractive force attachment element and the method further includes, when any one or more of the forces measured in (b) reach a predefined limit tending toward allowing relative movement between the variable force attractive element and the said vessel in a direction parallel to such force(s) measured, the controlling to increase the attractive force between the vessel surface and the variable attractive force attachment element in response to the force(s) measured in (b).

3. A method as claimed in claims 1or 2 wherein the attractive force attachment element is a variable attractive force attachment element and the method further includes, when any one or more of the forces measured in (b) reach a predefined limit tending toward allowing relative movement between the variable force attractive element and the said vessel in a direction parallel to such force(s) measured, the controlling to increase the attractive force between the vessel surface and the variable attractive force attachment element proportional to the force(s) measured in (b).

4. A method as claimed in claims 1or 2 wherein the attractive force attachment element is a variable attractive force attachment element and the method further includes, when any one or more of the forces measured in (b) reach a predefined limit tending toward allowing relative movement between the variable force attractive element and the said vessel in a direction parallel to such force(s) measured, the controlling by increasing of the attractive force between

the vessel surface and the variable attractive force attachment element when the force(s) measured in (b) reaches a maximum limit of a predetermined range.

5. A method as claimed in any one of claim 1 to 4 wherein the force(s) measured in (b) between the attractive force attachment element and the base structure is continuously monitored and determined from a signal responsive to a transducer, wherein said signal responsive to said transducer is displayed on the vessel visually, to indicate the force (s) between vessel and said fixed structure of said mooing robot.

6. A method as claimed in any one of claims 1 to 5 wherein said system included a plurality of spaced apart mooring robots, each presenting an attractive force attachment element to engage to a surface of said vessel and wherein the force(s) as measured in (b) between the attractive force attachment element and the base structure of each mooring robot is continuously monitored and determined from a signal responsive to a transducer, wherein said signal responsive to said transducer is displayed on the vessel visually, to indicate the force (s) between vessel and said fixed structure of said mooing robot.

7. A method as claimed in any one of claims 1 to 6 wherein said system included a plurality of spaced apart mooring robots, each presenting an attractive force attachment element to engage to a surface of said vessel, wherein said method further includes, when any one or more of the forces measured in (b) of one of said mooring robots tends toward allowing relative movement between the attractive force attachment element and the said vessel in a direction parallel to such force(s) measured by such approaching a holding capacity of the attractive force attachment element in any such direction, at least one of the other mooring robots is controlled for movement of its attractive force attachment element relative to said fixed base in a direction to vary the force between its attractive force attachment element and its base structure in a direction opposite to such said direction to thereby reduce the force in such said direction between the attractive force attachment element and its said base structure of said one mooring robot.

8. A method as claimed in any one of claims 1 to 7 wherein said system included a plurality of spaced apart mooring robots, each presenting a variable attractive force attachment element to engage to a surface of said vessel, wherein said method further includes, when any one or more of the forces measured in (b) of one of said mooring robots tends toward allowing relative movement between the variable force attractive element and the said vessel in a direction parallel to such force(s) measured by such approaching a holding capacity of the attractive force attachment element in any such direction, at least one of the other mooring robots is controlled to increase its attractive force.

9. A method as claimed in any one of claims 1 to 7 wherein the attractive force between each attractive force attachment element and the vessel surface is measured and a signal corresponding to the measured attractive force is transmitted for the purpose of its display on the vessel.

10. A method as claimed in any one of claims 1 to 9 wherein the attractive force between said attractive force attachment element and the vessel surface is measured and a signal corresponding to the measured attractive force is transmitted for the purpose of comparison with the measured force(s) of (b), wherein an alarm is triggered when any one or more of the forces measured in (b) reaches a proportion of a force required to result in relative movement between said attractive force attachment element and said vessel, which holding force is dependent on attractive force measured.

11. A method as claimed in any one of claims 1 to 10 wherein the attractive force between said attractive force attachment element and the vessel surface is measured and a signal corresponding to the measured attractive force is transmitted for the purpose of comparison with the measured force(s) of (b), wherein the attractive force is increased when any one or more of the forces measured in (b) reaches a limit corresponding a force (holding force) required to result in relative movement between said attractive force attachment element and said vessel, which holding force is dependent on attractive force measured.

12. A method as claimed in claim 1 to 11 wherein the attractive force

attachment element is of a kind to be engaged with a planar surface of said vessel with its attractive force acting normal only to said planar surface, wherein the attractive force between each attractive force attachment member and the planar surface is measured and a signal corresponding to the measured attractive force is transmitted for the purpose of comparison with the force measured in (b) (ii) wherein an alarm is triggered when such force in a direction to tend toward resulting in a relative movement of said attractive force attachment member and said vessel in the direction parallel to the force measured in (b) (ii), approaches the holding capacity of said attractive force attachment member with said vessel as determined from the measured attractive force.

13. A method as claimed in any one of claims 1 to 12 wherein the attractive force attachment element is of a kind to be engaged with a planar surface of said vessel with its attractive force acting normal only to said planar surface and is of a variable attractive force attachment element, wherein the attractive force between each attractive force attachment member and the planar surface is measured and a signal corresponding to the measured attractive force is transmitted for the purpose of comparison with the force measured in (b) (ii) wherein when such force in a direction reaches a predefined limit tending toward resulting in a relative movement of said attractive force attachment member and said vessel in the direction parallel to the force measured in (b) (ii), approaches the holding capacity of said attractive force attachment member with said vessel, the attractive force is increased.

14. A method as claimed in any one of claims 1 to 13 wherein when the force between the mooring robot and the vessel parallel to the direction of force measured in (b) (i) tends toward resulting in a separation of said attractive force attachment element from said vessel, exceeds a first threshold the mooring robot adopts a safe mode wherein the attractive force between the vessel surface and the attractive force attachment element changes to a maximum attractive force.

15. A vessel mooring system which includes

at least two mooring robots secured to a terminal, the terminal being either

a fixed or floating structure each mooring robot including an attractive force attachment element displaceably engaged to a base structure of said mooring robot said base structure fixed relative to the terminal, said attractive force attachment element to be releasably engaged with a substantially vertically extending port or starboard side disposed vessel surface for making fast the vessel to said terminal, said attractive force attachment element capable of exerting an attractive force normal to said vessel surface at which it is to be attached,

means to establish the attractive force between said vessel and said attractive force attachment element

wherein each mooring robot includes means to actuate movement of the attractive force attachment element relative to the base structure in at least a direction selected from any one or both of an athwartship direction and longitudinal direction

and wherein for each robot, said system further including

(a) a means to measure the attractive force between the attractive force attachment element and the vessel in a direction parallel to said normal to provide an "attractive force capacity reading" and

(b) means to measure the force between said attractive force attachment element and the base structure of said mooring robot in at least any one or more of:

i. a direction parallel to the said normal to provide a "normal force reading"

ii. a direction horizontal and perpendicular to said normal to provide a "horizontal shear force reading", and

iii. a direction vertical and perpendicular to the normal to provide a "vertical shear force reading"

(c) means to monitor the relationship between said attractive force capacity reading and any one or more of said normal force reading, horizontal shear force reading, and vertical shear force reading to

provide a or several "mooring status reading(s)"

(d) means to control each mooring robot responsive to said mooring status reading (s) in a manner such that when any one or more of normal force reading, horizontal shear force reading reaches a predefined limit, and vertical shear force reading in a direction tending to allowing a relative movement between said vessel and said attractive force attachment element of a said mooring robot, of the holding capacity of said attractive force attachment element in such direction, said means to control initiates at least one or more selected from the following:

i. said means to establish said attractive force in a manner to increase said attractive force,

ii. an alarm, and

iii. a displacement of the attractive force attachment element of at least one other mooring robot relative to its base structure, in a direction opposite to the direction tending to allowing a relative movement between said vessel and said attractive force attachment element of said mooring robot, to increase the loading force on said at least one other mooring robot and reducing the loading force on the said mooring robot in said direction tending to allowing a relative movement between said vessel and said attractive force attachment element of said mooring robot.

16. A vessel mooring system as claimed in claim 15 wherein said attractive force attachment element is a vacuum pad or cup and said means to establish the attractive force between said vessel and said attractive force attachment element is a vacuum system in fluid communication with said vacuum cup and includes a vacuum generator (preferably a vacuum pump).

17. A vessel mooring system as claimed in any one of claims 15 or 16 wherein at least two mooring robots ("bow set") are provided to be engaged proximate

more to the bow of a said vessel and at least two mooring robots ("stern set") are provided to be engaged proximate more to the stern of said vessel, wherein said means to control can control the attractive force of each attractive force attachment element and in a manner wherein when the attractive forces applied to the vessel surface by at least one of said mooring robot of each set reaches a first threshold the means to control operates in a manner to normalise the attractive force of each robot of each set.

18. A vessel mooring system which includes

at least two mooring robots secured to a terminal, the terminal being either a fixed or floating dock (or a second vessel) each mooring robot including an attractive force attachment element engaged to a base structure of said mooring robot said base structure fixed relative to the terminal, said attractive force attachment element to be releasably engaged with a vertically extending port or starboard side disposed vessel surface for making fast the vessel to said terminal, said attractive force attachment element capable of exerting an attractive force normal to said vessel surface at where it is to be attached,

means to establish the attractive force between said vessel and said attractive force attachment element

wherein for each robot, said system further including

(a) a means to measure the attractive force between the attractive force attachment element and the vessel to provide an "attractive force capacity reading" and

(b) means to measure the force between said attractive force attachment element and the fixed structure of said mooring robot at least in a direction parallel to the said normal to provide a "normal force reading"

(c) means to monitor the relationship between said attractive force capacity reading and said normal force reading to provide a "mooring status reading"

(d) means to control the mooring robot responsive to said mooring

status reading in a manner such that when the normal force reading in a direction tending to separate the attractive force attachment element from said vessel reaches an attractive force reading threshold, said means to control initiates at least any one or both of selected from the following:

i. said means to establish said attractive force in a manner to increase said attractive force, and

ii. an alarm.

19. A vessel mooring system as claimed in claim 18 wherein each mooring robot includes means to actuate translational movement of the attractive force attachment element relative to the base structure in at least an athwartship direction and wherein said means to control may in addition initiate a displacement of attractive force attachment element of an other robot of said system in the athwartship direction towards its said fixed structure thereby increasing the loading force of said other of said mooring robots dependent on such an other mooring robot having capacity determined from said attractive force capacity reading, to do so.

20. A vessel mooring system as claimed in claim 18 or 19 wherein said system further includes

a. means to determine shear force holding capacity between said attractive force attachment element and said vessel resultant from said attractive force capacity reading, in a horizontal direction and perpendicular to said normal, to provide a "shear force holding capacity reading"

b. means to measure the shear direction force, being a force parallel to said shear holding force, between said attractive force attachment element and said fixed structure of said mooring robot to provide a "shear force reading"

c. means to monitor the relationship between said shear force capacity reading and said shear force reading to provide a "second mooring

status reading"

wherein said means to control the mooring robot is also responsive to said second mooring status reading in a manner such that when the shear force reading in a direction tending to allowing relative movement of said vessel and said attractive force attachment element, reaches a predetermined limit, said means to control initiates at least one or more selected from the following:

i. said means to establish said attractive force in a manner to increase said attractive force, and

ii. an alarm.

21. A vessel mooring system as claimed in any one of claims 19 or 20 wherein said means to actuate translational movement of the attractive force attachment element is a linear actuator having an operation axis in the athwartship direction.

22. A vessel mooring system as claimed in any one of claims 19 to 21 wherein said means to actuate translational movement of the attractive force attachment element is a hydraulic linear actuator having an operation axis in the athwartship direction, said normal force measurement derived from a means to sense the hydraulic pressure of said hydraulic linear actuator.

23. A vessel mooring system for controlling the mooring of a vessel with a wharf facility said system comprising:

at least one mooring robot for releasably fastening to said vessel said mooring robot including

i. a fixed structure fastened to said wharf facility,

ii. an attractive force attachment element for releasable engagement with a planar vertical surface of vessel, said attractive force attachment element moveably disposed from said fixed structure to allow its relative movement to said facility in 3 orthogonal directions being a vertical direction, a first horizontal direction parallel to the normal of the vertical surface and a second horizontal direction parallel to the planar vertical surface

iii. means to actuate movement of the attractive force attachment element in at least said first and second horizontal direction

means to generate a force signal representative of the force between the fixed structure and said attractive force attachment element in a direction parallel to said first horizontal direction, and

means to generate a force signal representative of the force between the fixed structure and said attractive force attachment element in a direction parallel to said second horizontal direction

means to generate a force signal representative of the tensile holding force between said attractive force attachment element and said vessel in said first horizontal direction,

means to determine the shear holding force between said attractive force attachment element and said vessel in said second horizontal direction

means responsive to said first and second and third mentioned means to generate a force signal, which when one or more of

(a) the force measured by said first mentioned means to generate a force signal reaches a predefined value approaching the tensile holding force and

(b) the force measured by said second mentioned means to generate a force signal reaches a predefined value approaching the shear holding force

initiates any one or more selected from the following;

(a) an alarm and

(b) an increase in the attractive force of said attractive force attachment element with said vessel and

(c) the actuation means to change in the acceleration/deceleration of said attractive force attachment element relative to said wharf facility in a direction to reduce that force which is over said predefined value being one or both of:

i. the force between the fixed structure and said attractive attachment element in a direction parallel to said second horizontal direction and/or

ii. the force between the fixed structure and said attractive attachment element in a direction parallel to said first horizontal direction.

24. A mooring system for releasably affixing a vessel floating at the surface of a body of water to a terminal which is secured to the bottom of said body of water wherein said vessel is subjected to loading forces resultant from any one or more of wind, tides, water currents, waves, vessel loading levels, and movement actuated by said system, said system including

at least one mooring robot which includes

a) a base structure affixed to one of said terminal or said vessel,

b) an attractive force attachment element engaged to said base structure, said attractive force attachment element adapted to become affixed to and establish an attachment with a surface of the other of said one of said terminal or vessel, said attachment being of an attractive kind establishing an attractive holding force normal to the surface at which it is to attach,

a means to determine the attractive holding force of said attractive force attachment element when said attractive force attachment element is in an attached relationship with said surface

a means to determine the shear direction holding force of said attractive force attachment element with said surface when said attractive force attachment element is in an attached relationship with said surface, said shear direction holding force (herein after "horizontal shear direction holding force") being in a horizontal direction and perpendicular to said normal,

a means to determine at least one or more selected from the group comprising of

a. the force (herein after "tensile force") applied by said surface to said attractive force attachment element in a direction parallel to said normal, and

b. the force (herein after "horizontal shear force") applied by said surface to said attractive force attachment element in a horizontal direction and perpendicular to said normal, and

means for allowing comparison between

i) said the attractive holding force and said tensile force and

ii) said the horizontal shear direction holding force and said horizontal shear force.

25. A mooring system as claimed in claim 24 wherein said means for allowing comparison will initiate, when one or both of

i. said tensile force reaches a predetermined limit being a limit below the attractive holding force but approaching said attractive holding force in a direction to tend towards the release of said attractive force attachment element with said surface, and

ii. said horizontal shear force reaches a predetermined limit being a limit below the horizontal shear direction holding force but approaching said horizontal shear direction holding force in a direction to tend towards a relative movement in a horizontal direction between said surface and said attractive force attachment element,

one or more selected from

i. a means to establish and vary said attractive force, in a manner to increase said attractive holding force, and

ii. an alarm.

26. A mooring system as claimed in claims 24 or 25 wherein said means to determine the attractive holding of said attractive force attachment element when said variable attractive force attachment element is in an attached relationship

with said surface includes a sensor responsive to force between said attractive force attachment element and said surface in a direction normal to said surface and a means responsive to the signal from said sensor to determine the effective attractive holding force.

27. A mooring system as claimed in any one of claims 24 to 26 wherein said attractive force attachment element is movably engaged to said base structure by a linkage mechanism and there is provided means to actively actuate the movement of said variable attractive force attachment element relative to said base structure parallel to said horizontal shear force direction and parallel to said tensile force direction.

28. A mooring system as claimed in any one of claims 24 to 27 wherein said attractive force attachment element is movably engaged to said base structure by a linkage mechanism and there is provided means to actively actuate the movement of said variable attractive force attachment element relative to said base structure parallel to said horizontal shear force direction and means to actively actuate the movement parallel to said tensile force direction wherein said means for allowing comparison may further initiate, when one or both of

i. said tensile force reaches a predetermined limit being a limit below the attractive holding force but approaching said attractive holding force in a direction to tend towards the release of said attractive force attachment element with said surface, and

ii. said horizontal shear force reaches a predetermined limit being a limit below the horizontal shear direction holding force but approaching said horizontal shear direction holding force in a direction to tend towards a relative movement in a horizontal direction between said surface and said attractive force attachment element,

a change in velocity (acceleration or deceleration) of said attractive force attachment element by one or both of said means to actively actuate the

movement in order for said tensile force and/or horizontal shear force to remain below their respective limits.

29. A mooring system as claimed in any one of claims 24 to 28 wherein said attractive force attachment element is a variable attractive force attachment element wherein its attractive force may be varied by a means to control the attractive force.

30. A mooring system as claimed in claim 29 wherein said attractive force attachment element is a vacuum cup defining a pressure controllable cavity when engaged with said surface and wherein said means to control the attractive force includes a vacuum inducing means which is in fluid communication with said cavity to control the pressure in said cavity.

31. A mooring system as claimed in any one of claims 24 to 30 wherein said means to determine the shear direction holding force of said attractive force attachment element with said surface when said attractive force attachment element is in an attached relationship with said surface also determines the shear direction holding force (herein after "vertical shear direction holding force") in a vertical direction and perpendicular to said normal and wherein a means to measure the force (herein after "vertical shear force") applied by said surface to said attractive force attachment element in a vertical direction and perpendicular to said normal is provided, for the purposes of comparison of said vertical shear direction holding force with said vertical shear force.

32. A mooring system as claimed in claim 31 wherein said means for allowing comparison will also initiate, when said vertical shear force reaches a predetermined limit being a limit below the vertical shear direction holding force but approaching said vertical shear direction holding force in a direction to tend towards a relative movement in a vertical direction between said surface and said attractive force attachment element,

one or more selected from

i. a means to establish and vary said attractive force, in a manner to increase said attractive holding force, and

ii. an alarm.

33. A mooring system as claimed in any one of claims 24 to 32 wherein said means to determine the horizontal shear force and/or tensile force includes a means to measure responsive to such force(s) and a means to read said means to measure said means to read providing a signal useable by said means allowing comparison

34. A mooring system as claimed in any one of claims 24 to 33 wherein said means to determine the attractive holding force includes a means to measure responsive to such force and a means to read said means to measure said means to read providing a signal useable by said means allowing comparison.

35. A mooring system as claimed in claim 34 wherein said attractive force attachment element is a vacuum cup defining a pressure controllable cavity when engaged with said surface and wherein said means to control the attractive force includes a vacuum inducing means which is in fluid communication with said cavity to control the pressure in said cavity, said means to measure responsive to said attractive force being a pressure transducer engaged with said mooring robot in manner to measure the pressure differential between the cavity of said vacuum cup and ambient atmospheric pressure.

36. A mooring system as claimed in any one of claims 24 to 35 wherein said means to measure the said horizontal shear direction holding force means is a means to calculate such horizontal shear direction holding force from said measured attractive holding force.

37. A mooring system as claimed in claim 36 wherein means to calculate includes a table of empirically collected attractive holding force varying and dependent horizontal shear direction holding force reflective numbers reliant on which said horizontal shear direction holding force can be determined.

38. A mooring system as claimed in any one of claims 29 to 37 wherein said means to actively actuate includes at least one hydraulic ram.

39. A mooring system as claimed in any one of claims 29 to 38 wherein a means to measure the displacement of said attractive force attachment element

relative to said base structure is provided

40. A mooring system as claimed in any one of claims 29 to 39 wherein an alarms is sounded when one of more of the limit of movement of said attractive force attachment element relative to said base structure is reached.

41. A mooring system as claimed in any one of claims 29 to 40 wherein the displacement of said attractive force attachment element relative to said base structure is visually represented.

42. A mooring system as claimed in any one of claims 24 to 41 wherein said attractive forces is able to be controlled by human input.

43. A mooring system as claimed in any one of claims 29 to 41 wherein said displacement is able to be controlled by human input.